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POSSIBILITY OF THE COMMERCIAL PRODUCTION OF LEMON-GRASS OIL IN THE UNITED STATES.

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INTRODUCTION.

Lemon-grass oil is the volatile oil distilled from the plant known botanically as *Cymbopogon citratus* DC. and commonly called lemon grass (fig. 1). It is lemon yellow to brownish in color, with a strong odor resembling that of the lemon verbena, and for many years has occupied a prominent place in the perfume industry. The value of this oil depends almost entirely upon its content of citral, which is used in the manufacture of ionone, or artificial violet. Considerable use is also found for the oil in the soap industry.

The principal regions where lemon-grass oil is produced are the Travancore Province and Madras Presidency of India and the island of Ceylon. Small quantities are regularly produced in other parts of the East Indies, and from time to time in many other parts of the world.

Exact figures are not available regarding the consumption of lemon-grass oil in the United States, but estimates place it at about 100,000 pounds annually.

For the past eight years the Bureau of Plant Industry has been conducting experiments in the growing of lemon grass in central

Florida, and during the course of the experiments field tests have been made with 13 varieties secured from eight different parts of the world.

SOIL AND CLIMATIC REQUIREMENTS OF LEMON GRASS.

The best results with lemon grass have been obtained on well-drained sandy loam (fig. 2), but this plant also does well on light sand, such as the high pine lands of the Florida peninsula. Newly cleared sandy pine land without the previous application of lime has also given good results. Soil which is poorly drained or underlain by hardpan within 3 feet of the surface should not be planted to lemon grass. Field tests have not been made on heavy clay lands, but the successful cultivation of the crop on that type of soil is regarded as doubtful.

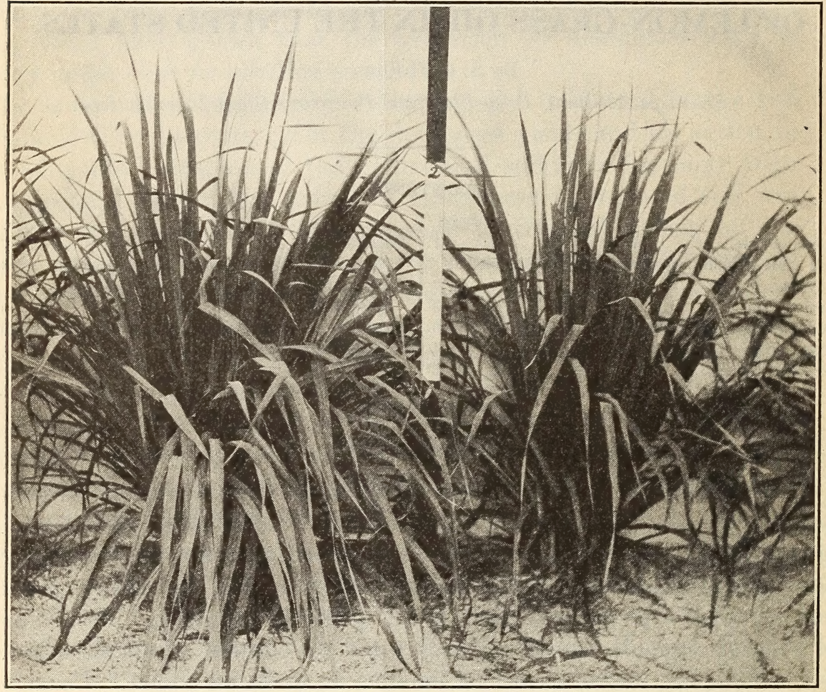

FIG. 1.—Two plants of lemon grass four months after planting.

The climatic requirements of lemon grass are subtropical. A winter temperature of 28° F. has killed the plants to the ground, while 24° has killed the roots. However, the crop may be planted with safety where the temperature does not fall below 25° F., and under certain conditions even a slightly lower temperature may not cause serious damage.

PROPAGATION.

Lemon grass does not produce seed in this country, although occasionally an abortive flower spike may be found on old, neglected plants. Propagation, therefore, is effected by division of the clumps. From each clump 25 to 50 divisions may be separated easily by tearing them off from the base of the mature plant. This should be accomplished by a sidewise pull, so that a few root fibers will be retained on each division. In case the old plants are to remain in their places the required number of divisions can be secured by pulling them off from the outer edge of the old clump. With a little practice these may be removed without loss of root fibers.

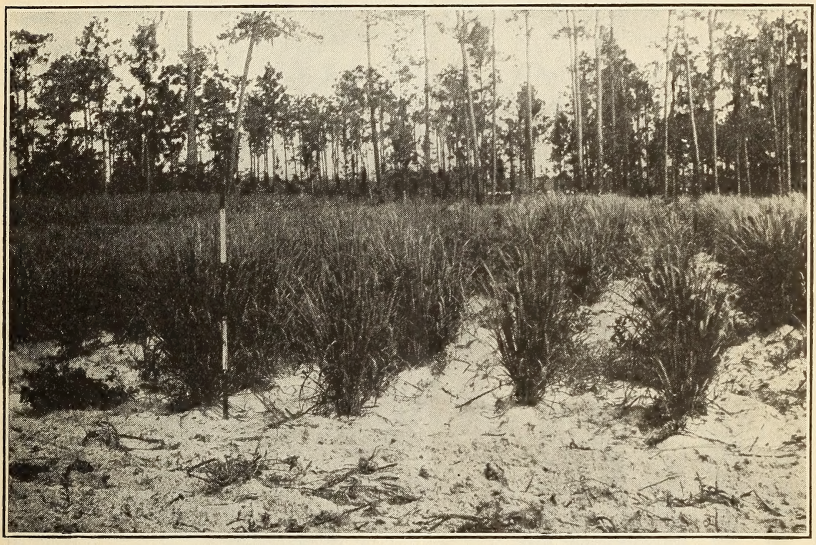

FIG. 2.—Lemon grass 3½ feet high six months after planting on sandy pine land.

Before planting, the tops of the divisions should be cut back to about 3 inches (fig. 3). The plants should be set in the early spring in rows 3 feet apart and about 18 inches apart in the row. This work should be done just after a rain or at a time when the soil is sufficiently moist not to require artificial watering.

FERTILIZERS AND CULTIVATION.

The results obtained from experimental fertilizer plats seem to indicate that on the sandy Florida soils rather more potash is required by lemon grass than by most grasses. Analysis shows a considerable variation in the percentage of nitrogen, phosphoric acid, and potash present in the plants of the different varieties tested. The results secured with one variety, which may be taken as a type, show that 5 tons of lemon grass contain 20.32 pounds of nitrogen, 33.20 pounds of potash, and 18.75 pounds of phosphoric acid. In the fertilizer tests a better growth was secured when the potash was applied in the form of the sulphate, and the results were more satisfactory when part of the nitrogen was applied in organic form. In the tests which have been made a fertilizer having 4 per cent nitrogen, 5 per cent potash, and 8 per cent phosphoric acid, applied at the rate of 600 pounds to the acre, has given the best results with the least cost. On soils of higher fertility a smaller quantity could be used. Although the use of larger quantities of fertilizers will give a heavier growth, it is by no means certain that the additional cost will be met by the increase in the crop.

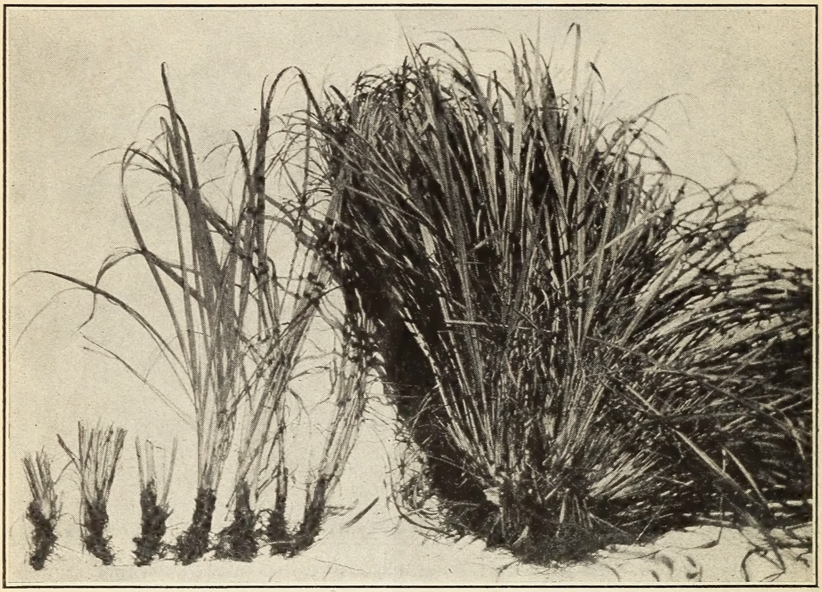

FIG. 3.—A mature clump of lemon grass, with divisions taken from it and trimmed for planting.

As soon as the plants have become well established in the field the fertilizer should be given as a side application and well worked in at the first cultivation. Cultivation should be frequent throughout the spring, to conserve the soil moisture, and throughout the summer all weeds should be kept down, as a few ill-smelling weeds in the crop at harvest time will greatly injure the odor of the oil. After the first year, only slight cultivation is needed, since after it is well established lemon grass tends to retard weed growth.

HARVESTING.

The first cutting should be made four or five months after planting, at which time the plants should be from 2½ to 3 feet high and the bunches from 8 to 10 inches in diameter. Although the plants will continue to grow throughout the summer, it has been found that after a certain size has been reached the increase in weight is less rapid; hence, it is more profitable to harvest the crop at the time stated and allow a new growth to develop. In the early fall of the first year a second cutting can be secured. After the first year the growth in the spring is more rapid and three harvests a year can be obtained. Harvesting can be accomplished by the use of a mowing machine so adjusted as to cut the plants about 8 inches above the ground. The cut material can be raked up with a horserake run crosswise of the rows.

In order to determine the proper stage and height at which the plants should be cut to produce the best yield and quality of oil, a number of tests were made, covering several years. In 1908 the plants were cut when they were 2 feet high. They were then tied in bundles, the bundles cut into three 8-inch lengths, and each portion distilled separately. The yield of oil obtained from each portion, together with the citral content of the oils, is shown in Table I.

TABLE I.—*Yield and citral content of lemon-grass oils distilled from plants 2 feet high.*

Portion of plant distilled.	Yield of oil.	Citral content of the oil.[1]
	Per cent.	*Per cent.*
Upper third	0.46	70
Middle third	.24	78
Lowest third	.10	82

[1] The citral content throughout all the experiments was determined by the sodium-sulphite method.

From these results, which are borne out by additional data obtained in succeeding years, the conclusion is evident that close cutting will not be profitable, because of the low oil content in the lower portion of the plant.

For the purpose of determining whether the hauling cost could be reduced by drying the plants before taking them to the still, the following test was made: A quantity of fresh plants was collected, well mixed, and divided into three portions. The first portion was distilled green, the second portion was exposed to the sun for several hours until the blades were nearly dry, and the third portion was dried in a loft for several hours at 110° F. The two dried portions were then distilled separately and the yield of oil calculated on the original green weight of the material. The results secured, together with the citral content of the oils, are given in Table II.

These results show that there was considerable loss of oil by drying the plants. In the case of the sun-dried plants the loss on a 4-ton crop would be 4.8 pounds of oil, or, at the prices prevailing for 1915, a loss of $3.84, which would more than pay for the extra hauling charge. Drying the plants seems to have no effect on the citral content of the oil, but on storing it was found that the solubility of the oil in alcohol diminished more rapidly in the oils from the dried material.

TABLE II.—*Yield and citral content of lemon-grass oils distilled from green and from dried plants.*

Condition of material.	Weight of material (green).	Weight of material (dried).	Yield of oil (based on green weight of material).	Citral content of the oil.
	Pounds.	*Pounds.*	*Per cent.*	*Per cent.*
Fresh	78.1		0.37	78
Sun dried	93.1	58.3	.31	78
Artificially dried	100.3	62.7	.32	79

DISTILLATION.

The apparatus required for the distillation of lemon-grass oil does not differ from that in general use for the distillation of other volatile oils. Before distilling the plants it has been found advisable to run them through a fodder cutter, in order to permit closer packing in the retort. From the data at hand it is estimated that if the plants are cut into 2-inch lengths a retort will hold 100 pounds of material for every 6 cubic feet of space, but if the plants are put in whole the quantity which the retort can hold will be somewhat less. The closer packing, however, in no way facilitates distillation.

In a retort having a capacity of 30 cubic feet a charge of 3,000 pounds can be distilled in 2 to 2½ hours by the steam which may be readily generated in a small farm boiler, and by the use of a larger volume of steam the time can be much reduced.

In this connection it is interesting to note that distillation under 20 pounds pressure in the retort increased the yield of oil, but gave an oil of very dark color and with lower citral content.

After the oil has been distilled it should be freed from water so far as possible in a separatory funnel, then dried by shaking with anhydrous calcium chlorid, and filtered. It should be stored in well-filled air-tight containers in as cold a place as possible until ready to be shipped to market. The shipping can be done in new and clean tin cans without injury to the product.

In order to determine whether any appreciable quantity of oil would be lost by discarding the distilled water coming over with the oil, a series of tests was made in 1915. The water from a number of charges of several pounds each was retained and each lot separately redistilled. In the apparatus used in the experiments about 1 gallon of water was secured for each 22 pounds of herb in the charge. The average of the results secured by the redistillation of this water showed that 1.2 gram of oil was dissolved in each gallon of water, a quantity too small to make its recovery profitable. Examination of this recovered oil showed its characteristics to be practically identical with the oil distilled directly from the herb.

VARIETIES.

During the many years that lemon grass has been cultivated a great variety of forms of the plant has been developed. Some years ago an attempt was made to divide the old species into two separate species, basing the descriptions partially on the character of the oil secured from the two sorts. In the essential-oil trade it long has been recognized that there is a wide difference in the characteristics of lemon-grass oils from different regions. It is not the purpose of this paper, however, to discuss any questions of systematic relationship or nomenclature of the plant, but since a wide difference has been found in the commercial value of the strains under experimental cultivation, a brief discussion of these will be of interest to the prospective grower.

During the course of the experiments, plants were obtained from a number of sources, and altogether 13 different strains have been tested. Following are the sources of the various strains:

1. Secured from a nursery in Florida. The original stock was from Havana.
2. A local form sold in the Florida nursery trade.
3. Isle of Pines.
4. Porto Rico.
5. Cochin China.
6. Ceylon.
7. Mexico.
8. India.
9. India.

10, 11, and 12. Origin unknown.

13. Ceylon.

These 13 strains fall into the following classes as regards growth characteristics:

(1) The West Indian type, represented by Nos. 1, 2, 3, and 4. The plants are 2½ to 3 feet high, with lax, drooping leaves and of light color.

(2) The East Indian type, represented by Nos. 5, 8, and 9. The plants are 3½ to 4 feet high and erect. The leaves are rather erect and more scabrous than the West Indian form.

(3) The Mexican form, represented by No. 7. This is a weak form, very drooping in habit, with lax leaves and very light in color.

No. 6 has the typical West Indian appearance, but is markedly different in oil yield. No. 13 has the typical East Indian appearance, except the color, which is very light, almost yellowish. Nos. 10, 11, and 12 are of the approved East Indian type.

Table III shows the variations in the yield of oil and the citral content of the oil from these various types for the season of 1915.

TABLE III.—*Yield and citral content of lemon-grass oils distilled from the various plants under cultivation in 1915.*

Variety.	Yield of oil.	Citral content of the oil.	Variety.	Yield of oil.	Citral content of the oil.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
No. 1	0.24	80	No. 9	0.20	76
No. 5	.27	70	No. 10	.23	80
No. 6	.16	73	No. 11	.28	80
No. 7	.23	72	No. 12	.29	81
No. 8	.15	79	No. 13	.12	85

It has been found year by year that there is considerable variation in both the yield of oil and the citral content, yet the figures given in Table III may be taken as representative of the varieties mentioned. It will be noted that the Ceylon forms, Nos. 6 and 13, are very low in oil yield, and the same is true of No. 8, from India.

Both the yield of oil and the citral content of the oil have been found to be affected to a considerable degree by the type of soil on which the plants are grown. Therefore, before selecting a variety for commercial planting, tests should be made to determine which variety will give the highest yield of oil per acre and the highest citral content on the land to be used. The vigor of the plants should also be considered, since there seems to be a difference in soil requirements among the varieties tested.

FACTORS AFFECTING THE YIELD OF LEMON-GRASS OIL.

Soil conditions.—In order to determine the effect of soil conditions on the yield of lemon-grass oil, tests were made in 1908 with the West Indian variety, No. 1, on soils containing various degrees of moisture. On light sandy soil of the high hammock type the yield of oil was 0.31 per cent, and on moist bottom land 0.27 per cent. Another test on sandy high pine land in a different location gave an oil yield of 0.35 per cent, and on moist land near the lake 0.28 per cent. Further tests with this variety under other conditions of soil moisture gave results which were also much in favor of the sandier and better drained land. In 1915 the plat devoted to the Ceylon variety, No. 6, showed a higher yield of oil from the plants grown on the high, well-drained, sandy soil than from the part of the plat which contained slightly more moisture, 0.16 per cent being obtained from the former and only 0.11 per cent from the latter. Similar results were secured in 1914 with varieties Nos. 5, 8, and 9.

The evidence thus far available indicates that for all the forms of lemon grass tested, a heavy growth of herb with high oil content is to be expected on light, well-drained soil of the high pine type.

Time of harvest.—Since lemon grass is a perennial crop and two or three cuttings can be made each year, it is of interest to note the difference in yield of oil secured from the plants at each harvest. In Table IV are given the results obtained from each of two harvests for various years.

TABLE IV.—*Yield of lemon-grass oil distilled from plants harvested at two different times of the year.*

Year and plants harvested.	Yield of oil.		Year and plants harvested.	Yield of oil.	
	First harvest.	Second harvest.		First harvest.	Second harvest.
1908.	*Per cent.*	*Per cent.*	1914—Continued.	*Per cent.*	*Per cent.*
First plat	0.31	0.33	No. 8	0.12	0.38
Second plat	.40	.48	No. 9	.24	.36
Third plat	.20	.35			
1912.			1915.		
No. 1	.40	.36	No. 1	.27	.26
No. 8	.28	.46	No. 8	.11	.11
1914.			No. 9	.19	.17
No. 1	.37	.50	No. 10	.23	.47
No. 5	.34	.35	No. 11	.28	.40
No. 6	.16	.20	No. 12	.29	.31
			No. 13	.12	.27

These results show that in general the percentage of oil is higher in the second cutting. In the first year of planting, however, the quantity of herb obtained in the second cutting is much less than that from the first cutting; consequently, the acre yield of oil in the first year would be greater from the first cutting rather than from the second.

FACTORS AFFECTING THE CITRAL CONTENT OF LEMON-GRASS OIL.

Closeness of cutting the plants.—Experiments conducted with variety No. 1, grown on very light sandy soil, showed that the citral content was highest in the part of the plant nearest the ground. Large plants divided into three portions yielded, on distillation, oil with citral content as follows: Upper portion, 70 per cent; middle portion, 78 per cent; and lowest portion, 82 per cent. A similar test made with variety No. 5 divided into only two portions yielded oil with citral content in favor of the lower portion, as follows: Upper portion, 74 per cent; lower portion, 76 per cent. These results show that the closest cutting which gives a profitable yield of oil also produces a better quality of oil.

Soil moisture.—Plants of variety No. 1, grown on soils having varying degrees of moisture, yielded oil with citral content as follows: On dry sandy soil, 75 per cent citral; on slightly moist sandy loam, 68 per cent; and on moist loam near the lake, 66 per cent. Further tests with other varieties on different types of soil have given similar results. This would indicate that high citral content can be secured only from plants grown on very well drained soil.

Time of harvest.—Although the citral content of the oil does not appear to be greatly affected by the time of harvest, the results indicate that of the two harvests each year the oil distilled from plants of the first harvest contains the greater quantity of citral. Data covering a number of years are given in Table V.

TABLE V.—*Citral content of lemon-grass oil distilled from plants harvested at two different times of the year.*

Year and plants harvested.	Citral content of oil.	
	First harvest.	Second harvest.
1908.	*Per cent.*	*Per cent.*
First plat	72	74
Second plat	74	72
Third plat	75	72
1912.		
No. 1	76	78
No. 8	78	76
1914.		
No. 1	78	....
No. 5	78	76
No. 6	77	79
1914—Continued.	*Per cent.*	*Per cent.*
No. 8	81	72
No. 9	75	59
1915.		
No. 5	70	68
No. 6	73	71
No. 8	77	64
No. 9	78	70
No. 10	80	74
No. 11	80	82
No. 12	81	80
No. 13	85	82

SOLUBILITY OF LEMON-GRASS OIL IN ALCOHOL.

For many years it was considered that good lemon-grass oil should be soluble in clear solution in three volumes of 70 per cent alcohol, and this was the test applied before the method of citral determination was in general use. It served a useful purpose, however, inasmuch as certain adulterations which had become quite general could thus be detected, but at the present time, when the valuation of the oil is entirely on the basis of the citral content, it is difficult to understand the reason for the continued use of the solubility test. It has been shown repeatedly that in many parts of the world pure lemon-grass oil does not pass the solubility test, especially after it has been stored for several months. This has been true of most of the samples of the oils produced in the Western Hemisphere, so that West Indian lemon-grass oil has come to be a synonym for insoluble oil. This discrimination has kept out of the market many West Indian oils of very high citral content.

There has been much discussion regarding the factors which affect the solubility of the oil, it having been contended that the length of time of distillation is the controlling factor. In order to secure data upon this point the following tests were made: In 1914, 158 pounds of the freshly cut plants were distilled with steam and the oil drawn off in fractions at intervals of 45 and 60 minutes, respectively. The first fraction represented a yield of oil of 0.28 per cent, the citral content of the oil being 80 per cent, while the second fraction represented a yield of 0.04 per cent of oil, with a citral content of 85 per cent. When first distilled the first fraction gave a slightly cloudy solution with three volumes of 70 per cent alcohol, but after two months it gave a very cloudy solution in all volumes of 70 per cent alcohol. The second fraction was soluble with clear solution in three volumes of 70 per cent alcohol, showing no sign of change after two months. Another sample of 203 pounds of the fresh plants distilled with steam and the oil drawn off in fractions at intervals of 15, 15, 20, and 40 minutes, respectively, gave the results shown in Table VI.

TABLE VI.—*Citral content and solubility in 70 per cent alcohol of various fractions of lemon-grass oil.*

Fractions.	Yield of oil.	Citral content of oil.	Solubility in 70 per cent alcohol.
	Per cent.	*Per cent.*	
First 15 minutes	0.21	39	Soluble with very cloudy solution in two volumes and over.
15 to 30 minutes	.21	74	Soluble in clear solution in two volumes and over.
30 to 50 minutes	.05	82	Do.
50 to 90 minutes	.01	80	Do.

From the results shown in Table VI it is evident that complete extraction of the oil gives a product of greater solubility and higher citral content.

The oils produced in Florida from all varieties of the plant have passed the solubility test when first distilled, but after storing for three months all have become insoluble. At the present time there is a decided tendency to disregard the solubility test, and no difficulty has been encountered in selling the Florida oils at a good price when the citral content was 70 per cent or more.

COMMERCIAL POSSIBILITIES.

The consumption of lemon-grass oil in the United States for the manufacture of ionone and for perfumery purposes is continually increasing, and it is believed that the demand is sufficient to warrant an attempt to grow the plant for the commercial production of the oil in such parts of the country as possess the proper climatic requirements. Tests on acre plats have been made to determine the cost of production, the best methods of distilling the oil, and the quality of the product. Samples of the oil produced have been sold on the market at the prices prevailing for the better grades of imported oil, and it seems possible to produce the oil commercially at a fair profit.

From the experiments made thus far the following estimates are given of the cost of production and the returns that may be expected for this crop under average conditions:

EXPENDITURES.

First year (per acre):	
Preparing the land	$3.00
Planting	2.00
Fertilizers	8.00
Cultivation	2.00
Harvesting and distilling	5.00
Total expenditures, first year	20.00
Succeeding years (per acre):	
Cultivation	1.00
Fertilizers	8.00
Harvesting and distilling	8.00
Total expenditures, second year and succeeding years	17.00

RETURNS.

First year: 25 pounds of oil per acre, at 80 cents	20.00
Succeeding years: 35 pounds of oil per acre, at 80 cents	28.00

In these statements no allowance is made for such charges as taxes, insurance, interest, or depreciation of outfit. It is doubtful whether the production of lemon-grass oil would be profitable if all overhead charges were placed against this crop alone, since the distilling plant would be in use only a few weeks in a year. However, if grown in connection with other volatile-oil plants, so that a long distilling season would be secured, it is believed that this crop will yield returns comparing favorably with other crops grown on the same type of land.

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